Draft Macroeconomic Impacts of AB 32 & SB 375 on the SCAG Economy: Methodological Summary

I. Introduction and Overview

Assembly Bill (AB) 32 has established greenhouse gas (GHG) emissions reduction goals and limits and has identified a series of policy actions and mechanisms that can achieve them at the sector-based and economy-wide levels. In addition, Senate Bill (SB) 375 directs the Air Resources Board to set regional targets for the reduction of GHGs in the transportation sector through regional and local actions that reduce transportation demand. These actions are intended to help California achieve GHG reduction goals for cars and light-duty trucks under AB 32.

The major focus of economic analysis of environmental legislation until recently has been on the direct, or on-site, impacts of individual mitigation policies or collective scenarios. Some of these policy options and scenarios can result in cost-savings directly to those who implement them, but they also provide gains to their customers if the savings are passed on in the form of lower prices. It is also likely that some other options will incur additional costs to businesses, households, non-profit institutions, and government operations, and the likely cutback in economic activity will also affect their suppliers.

Complicating the situation are various types of indirect effects stemming from the interdependence of the economy. Increases in demand ripple through the economy generating a set of successive rounds of positive supplier multiplier effects. Cost savings are passed along to several rounds of customers to add further to the stimulus. Decreases in demand will have their own ripple effects on different sets of suppliers and customers in an analogous negative way (see, e.g., Rose and Oladosu, 2002; Rose and Wei, 2009a and 2009b; Miller et al., 2009).

The purpose of this summary is to describe the methods we will use to estimate the economy-wide impacts on the SCAG Region of specific AB32 policies and measures, and cap & trade, as well as specific SB 375 transportation and land use planning policy options. It is divided into 5 sections. Section 2 summarizes the choice of the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI[+]) Model and the TranSight (TS) Model that we will use to estimate the macroeconomic impacts. Section 3 presents an overview of how we translate the results of the microeconomic analysis into REMI simulation policy variables, as well as how the data are further refined and linked to key structural and policy variables in the Model. Section 4 summarizes the set-up process of policy simulations in the REMI PI[+] model. Section 5 lists the output variables of the model, and briefly describes sensitivity analyses that will be performed to ensure the results will be robust. The Appendices provide more detail on the REMI model and modeling alternatives.

II. REMI Model Analysis

Several modeling approaches can be used to estimate the total regional economic impacts of environmental policy, including both direct (on-site) effects and various types of indirect (off-site) effects. These include: input-output (I-O), computable generated equilibrium (CGE), mathematical programming (MP), and macroeconometric (ME) models. Each has its own strengths and weaknesses (see, e.g., Rose and Miernyk, 1989; Partridge and Rickman, 1998).

The choice of which model to use depends on the purpose of the analysis and various considerations that can be considered as performance criteria, such as accuracy, transparency, manageability, and costs. After careful consideration of these criteria, we chose to use the REMI PI$^+$ Model and the TS Model. The REMI PI$^+$ Model is superior to the others reviewed in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy (see Appendix B). With careful explanation of the model, its application, and its results, it can be made as transparent as any of the others. Moreover, the research team has used the model successfully in similar analyses in the states of Florida, Pennsylvania, Michigan and Wisconsin (Rose and Wei, 2009a; Rose and Wei, 2009b; Miller et al., 2009). The REMI TS Model is similar to PI$^+$ but adds an economic geography dimension that allows consideration of policies that alter the transportation network, transportation choices and land use patterns.

The REMI Model has evolved over the course of 30 years of refinement (see, e.g., Treyz, 1993). It is a (packaged) program, but is built with a combination of national and region-specific data. Government agencies in practically every state in the U.S. have used a REMI Model for a variety of purposes, including evaluating the impacts of the change in tax rates, the exit or entry of major businesses in particular or economic programs in general, and, more recently, the impacts of energy and/or environmental policy actions.

A detailed discussion of the major features of the REMI Model is presented in appendix A. We simply provide a summary for general readers here. A macroeconometric forecasting model covers the entire economy, typically in a "top-down" manner, based on macroeconomic aggregate relationships such as consumption and investment. REMI differs somewhat in that it includes some key relationships, such as exports, in a bottom-up approach that allows evaluation of specific sector-based policy options. In fact, it makes use of the finely-grained sectoring detail of an I-O model, i.e., it divides the economy into 169 sectors, thereby allowing important differentials between them. This is especially important in a context of analyzing the impacts of GHG mitigation actions, where various options were fine-tuned to a given sector or where they directly affect several sectors somewhat differently. The less expensive 70-sector REMI Model would not be satisfactory because it does not provide sufficient detail with respect to utilities and manufacturing. In the 70-sector model, electricity, gas, and water are combined into one sector, as opposed to being in separate categories in the 169-sector model. The 70-sector model divides the economy into only 22 manufacturing sectors, while the 169-sector model has 84 manufacturing sectors.

The TS Model currently includes the 70-sector REMI I-O model industry detail. The TS Model adds a great deal of new information to the PI$^+$ Model with the inclusion of gravity models to account for the regional economic geography. This allows the model to translate highway and

transit investments and traveler behavioral changes into inputs to the macro model. As REMI does not offer a version of the TS Model at the 169-sector level at this time, the study team will evaluate the energy impacts with PI$^+$ and will evaluate transportation infrastructure impacts with TS.

Moreover, rather than using just a model for the 6-county SCAG Region, it would be best to use a 3-region REMI Model (at modest additional cost). This would include the SCAG Region, Rest of CA and REST of the U.S. This would be useful in gauging industrial leakage from the SCAG region due to the implementation of AB32 or SB 375 policies.

The macroeconomic character of the model is able to analyze the interactions between sectors (ordinary multiplier effects) but with some refinement for price changes not found in I-O models. The REMI Model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

The econometric feature of the model refers to two considerations. The first is that the model is based on inferential statistical estimation of key parameters based on pooled time series and regional (panel) data across all states of the U.S. (the other candidate models use "calibration," based on a single year's data).[1] This gives the REMI PI$^+$ and REMI TS models an additional capability of being better able to extrapolate[2] the future course of the economy, a capability the other models lack. The major limitation of the REMI PI$^+$ and REMI TS models versus the others is that it is pre-packaged and not readily adjustable to any unique features of the case in point. The other models, because they are based on less data and a less formal estimation procedure, can more readily accommodate data changes in technology that might be inferred, for example from engineering data. However, our assessment of the REMI PI$^+$ and REMI TS models is that these adjustments were not needed for the purpose at hand.

The use of the REMI PI$^+$ and REMI TS models will involve the generation of a baseline forecast of the economy through 2020, consistent with the SCAG baseline forecast. Then simulations are run of the changes brought about through the implementation of the various GHG mitigation policy options. This includes the direct effects in the sectors in which the options are implemented, and then the combination of multiplier (purely quantitative interactions), general equilibrium (price-quantity interactions), and macroeconomic (aggregate interactions) impacts. The differences between the baseline and the "counter-factual" simulation represent the total state economic impacts of these policy options. The TS model also adds the benefits of improved access or the costs of restricted access on transactions in the SCAG economy.

III. Input Data

The quantification analysis of the costs/savings of policy options in the microeconomic analysis of this project is limited to the direct effects of their implementation. For example, the direct costs of an energy efficiency option include the energy customers' expenditure on energy efficiency

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[1] REMI is the only one of the models reviewed that really addresses the fact that many impacts take time to materialize and that the size of impacts changes over time as prices and wages adjust. In short, it better incorporates the actual dynamics of the economy.

[2] The model can be used alone for forecasting with some caveats, or used in conjunction with other forecast "drivers".

equipments and devices. The direct benefits of this option include the savings on energy bills of the customers.

Before undertaking any economic simulations, the costs and savings for the policy options are translated to model inputs that can be utilized in the Model. This step involves the selection of appropriate policy levers in the REMI PI$^+$ and REMI TS models to simulate the policy's changes. The input data include sectoral spending and savings over the full time horizon (2010-2020) of the analysis.

Major outputs from the micro analysis that we will use include the following, among others:

- GHG emissions reductions by sector and policy option
- Change in Electricity generation capacity and generation output by fuel type
- Change in Electricity sales by sector and policy option
- Change in Fuel prices by sector and policy option
- Change in Fuel expenditures by sector and policy option
- Change in Capital Investment by sector and policy option
- Change in O&M Cost by sector and policy option

In this study we will perform analysis on two sets of GHG mitigation policy options: non-transportation policies and measures (e.g. Energy Efficiency, RPS, CHP) and the policy options implemented under programs covering other sectors, including price and non-price mechanisms.

In addition, the transportation policy options that affect the SCAG region transportation network will be evaluated with the TS Model. This will require the exercise of the SCAG Travel Demand Model to capture the travel impacts of groups of policy options.

In Table 1, we choose Energy Efficiency to illustrate how we will translate, or map, the potential micro results into REMI PI$^+$ economic variable inputs. The first set of inputs in Table 1 is the increased cost to the commercial, industrial, and residential sectors due to the purchases of energy efficient equipment and appliances. For the commercial and industrial sectors, this is simulated in REMI by increasing the value of the "Capital Cost" variable of individual commercial sectors and individual industrial sectors under the "Compensation, Prices, and Costs Block." For the residential sector, the program costs (which represent total incremental costs of new equipment over conventional equipment) are simulated by increasing the "Consumer Spending" on "Kitchen & Other Household Appliances" (and decreasing all the other consumptions correspondingly). The "Consumer Spending (amount)" and "Consumption Reallocation (amount)" variables can be found in the "Output and Demand Block" in the REMI Model.

The second set of inputs is the corresponding stimulus effect to the economy of the spending on efficient equipment and appliances, i.e., the increase in the final demand for goods and services from the industries that supply energy efficient equipment and appliances. This is simulated in REMI by increasing the "Exogenous Final Demand" (in the "Output and Demand Block") of the following sectors: Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector; Electric Lighting Equipment Manufacturing sector; Electrical Equipment Manufacturing sector; and Other Electrical Equipment and Component Manufacturing

sector. The interest payment due to the financing of the capital investment is simulated as the "Exogenous Final Demand" increase of the Monetary Authorities, Credit Intermediation sector.[3] Any administrative cost of the Energy Efficiency program is simulated as the "Exogenous Final Demand" increase of the Management, Scientific, and Technical Consulting Services sector.

The third set of inputs to REMI is the energy savings of the commercial, industrial, and residential sectors resulted from the Energy Efficiency program. For the commercial and industrial sectors, the energy savings are simulated in REMI by decreasing the value of the "Electricity/Natural Gas/Residual Fuel Cost of All Commercial/Industrial Sectors" variables. These variables can be found in the "Compensation, Prices, and Costs Block." For the residential sector, the energy savings are simulated by decreasing the "Consumer Spending" on "Electricity", "Gas" and "Fuel Oil" (and increasing all the other consumption categories correspondingly). Again, the "Consumer Spending (amount)" and "Consumption Reallocation (amount)" variables can be found in the "Output and Demand Block" in the REMI model.

Table 1. Mapping Micro Analysis Outputs on Energy Efficiency into REMI Inputs

Quantification Results (ENERGY 2020 outputs plus additional necessary data from other sources)		Policy Variable Selection in REMI
Customer Outlay on Energy Efficiency (EE)	Businesses (Commercial and Industrial Sectors)	Compensation, Prices, and Costs Block →Capital Cost (amount) of individual commercial sectors→Increase
	Households (Residential Sector)	Output and Demand Block→Consumer Spending (amount)→Kitchen & other household appliances→Increase
		Output and Demand Block→Consumer Spending (amount)→ Bank service charges, trust services, and safe deposit box rental→Increase
		Output and Demand Block →Consumption Reallocation (amount)→All Consumption Sectors →Decrease
Investment on EE Technologies		Output and Demand Block →Exogenous Final Demand (amount) for Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector; Electric Lighting Equipment Manufacturing sector; Electrical Equipment Manufacturing sector; and Other Electrical Equipment and Component Manufacturing sector→Increase
Interest Payment of Financing Capital Investment		Output and Demand Block →Exogenous Final Demand (amount) for Monetary Authorities, Credit Intermediation sector→Increase

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[3] The opportunity cost of the interest payment is included in the increase of the "Capital Cost" variable for the commercial and industrial sectors (row 1 in Table 2). As for the residential sector, it is reflected in the reduction in consumption of all other commodities (i.e., this is reflected in a decrease in the "Consumption Reallocation" variable shown in row 2 in Table 2).

Quantification Results (ENERGY 2020 outputs plus additional necessary data from other sources)		Policy Variable Selection in REMI
Administrative Outlays		Output and Demand Block →Exogenous Final Demand (amount) for Management, Scientific, and Technical Consulting Services sector→Increase
Energy Savings of the Customers	Businesses (Commercial and Industrial Sectors)	Compensation, Prices, and Costs Block→Electricity, Natural Gas, and Residual (Commercial Sectors) Fuel Cost (share) of All Commercial Sectors→Decrease
		Compensation, Prices, and Costs Block→Electricity, Natural Gas, and Residual (Industrial Sectors) Fuel Cost (share) of All Industrial Sectors→Decrease
	Households (Residential Sector)	Output and Demand Block→Consumer Spending (amount)→Electricity, Gas, and Fuel Oil→Decrease
		Output and Demand Block →Consumption Reallocation (amount)→All Consumption Sectors →Increase
Energy Demand Decrease from the Energy Supply Sectors[a]		Output and Demand Block →Exogenous Final Demand (amount) for Electric Power Generation, Transmission, and Distribution sector; Natural Gas Distribution sector; and Petroleum and Coal Products Manufacturing sector→Decrease

[a] The final demand change here only reflects the energy consumption reductions from the commercial and industrial sectors. The residential sector energy consumption reductions will be entered into the model through the "Consumer Spending" variable.

The last set of inputs is the corresponding damping effects to the energy supply sector due to the decrease in the demand from the customer sectors. These effects are simulated by reducing the "Exogenous Final Demand" of the Electric Power Generation, Transmission, and Distribution sector, Natural Gas Distribution sector, and Petroleum and Coal Products Manufacturing sector in REMI. In this step, the final demand change is only modeled for the non-residential sectors, i.e., only the decreased demand from the commercial and industrial sectors need to be manually entered into the model as final demand change for the energy supply sectors. For the Residential sector, the model will internally convert the change in the Consumer Spending (amount) policy variable into changes in final demand for the corresponding sectors.

IV. Simulation Set-up in REMI

Figure 1 shows how a policy simulation process is undertaken in the REMI PI[+] model. First, a policy question is formulated (such as what would be the economic impacts of implementing the Energy Efficiency Programs). Second, external policy variables that would embody the effects of the policy are identified (take Energy Efficiency as an example, relevant policy variables would include incremental costs and investment in energy efficient appliances; final demand increase in the sectors that produce the equipments and appliances; and the avoided consumption of electricity, natural gas, etc.). Third, baseline values for all the policy variables are used to generate the control forecast (baseline forecast). In REMI PI[+], the baseline forecast uses the most recent data available (i.e., 2007 data) for the study region and the external policy variables are set equal to their baseline values. Fourth, an alternative forecast is generated by changing the values of the external policy variables. Usually, the changing values of these variables represent the direct

effects of the simulated policy scenario. Fifth, the effects of the policy scenario are measured by comparing the baseline forecast and the alternative forecast. Sensitivity analysis can be undertaken by running a series of alternative forecasts with different assumptions on the values of the policy variables.

In this study, we first run the REMI PI$^+$ model for each of the SCAG policy options *individually* in a comparative static manner, i.e., one at a time, holding everything else constant. Next, we run a *simultaneous* simulation in which we assume that all the policies are implemented together.

Then the simple summation of the effects of individual options is compared to the simultaneous simulation results to determine whether the "whole" is different from the "sum" of the parts. Differences can arise from non-linearities and/or synergies. The latter would stem from complex functional relationships in the REMI PI$^+$ Model.

Similar procedures will be followed for the transportation policy options. Simulations of these options will be run independently in REMI TS. These simulations will produce estimates of the macroeconomic effects of the transportation policy options. These macro impacts (e.g. output, income, employment, etc.) can be added to the energy impacts produced in the combined PI$^+$ Model simulations. As these two models undertake the simulation at different levels of detail, 70 verses 169 sectors, some benefits and costs of the interaction of these energy and infrastructure policies may not be accounted for. The REMI staff believes these lost impacts will be minor compared to the aggregate level of the impacts. The study team will evaluate these potential impacts during the study.
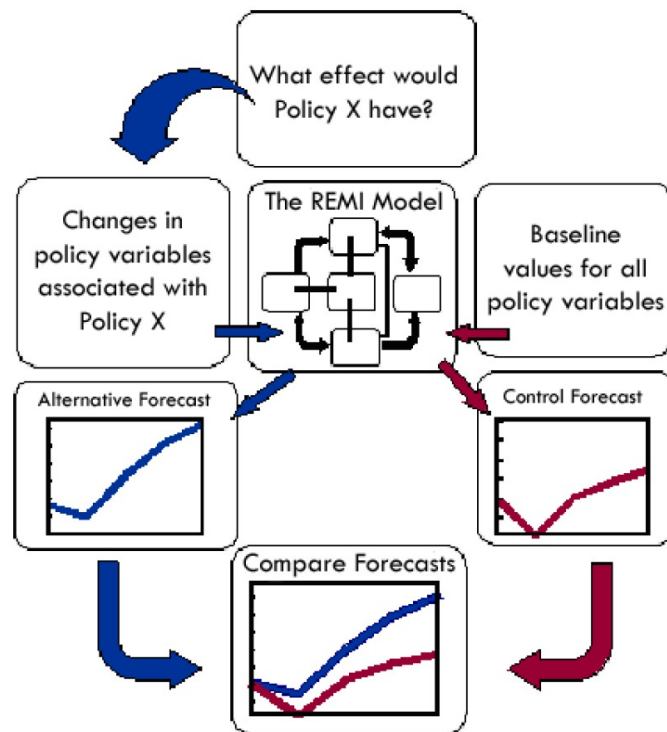

Figure 1. Process of Policy Simulation in REMI

V. Model Outputs

Simulations will be performed of the impacts of 2 sets of AB32 mitigation policies:

- Cap and trade
- Complementary policies, other than those related to Transportation and Land Use (Energy Efficiency, RPS, and CHP)

The policies will be simulated individually and combined. We will ascertain the extent to which the simple sum of the parts differs from the whole. Differences will be ascribable to a combination of non-linearities and synergies in the SCAG economy.

The REMI Model analysis will yield the following aggregate output variable impacts:

- Economic growth, or change in Gross State Product (GSP) by year
- Employment (job creation or losses)
- Personal Income
- Electricity, natural gas and petroleum prices
- Government revenues

In addition, we will provide impacts for each of the 169 sectors (70 for TS) of the SCAG economy.

Finally, sensitivity tests will be run on the following key variables:

- Energy prices
- Investment addition/displacement
- Discount rates

APPENDIX A. Description of the REMI PI⁺ Model

REMI PI⁺ (REMI, 2009) is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to wage, price, and other economic factors.

The REMI model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the model. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares. The blocks and their key interactions are shown in Figures A1 and A2.

The Output and Demand block includes output, demand, consumption, investment, government spending, import, product access, and export concepts. Output for each industry is determined by industry demand in a given region and its trade with the US market, and international imports and exports. For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities and population. Input productivity depends on access to inputs because the larger the choice set of inputs, the more likely that the input with the specific characteristics required for the job will be formed. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age and gender, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after tax compensation rate. Migration includes retirement, military, international and economic migration. Economic migration is determined by the relative real after tax compensation rate, relative employment opportunity and consumer access to variety.

**Figure A1. REMI Model Linkages (Excluding Economic Geography Linkages)**
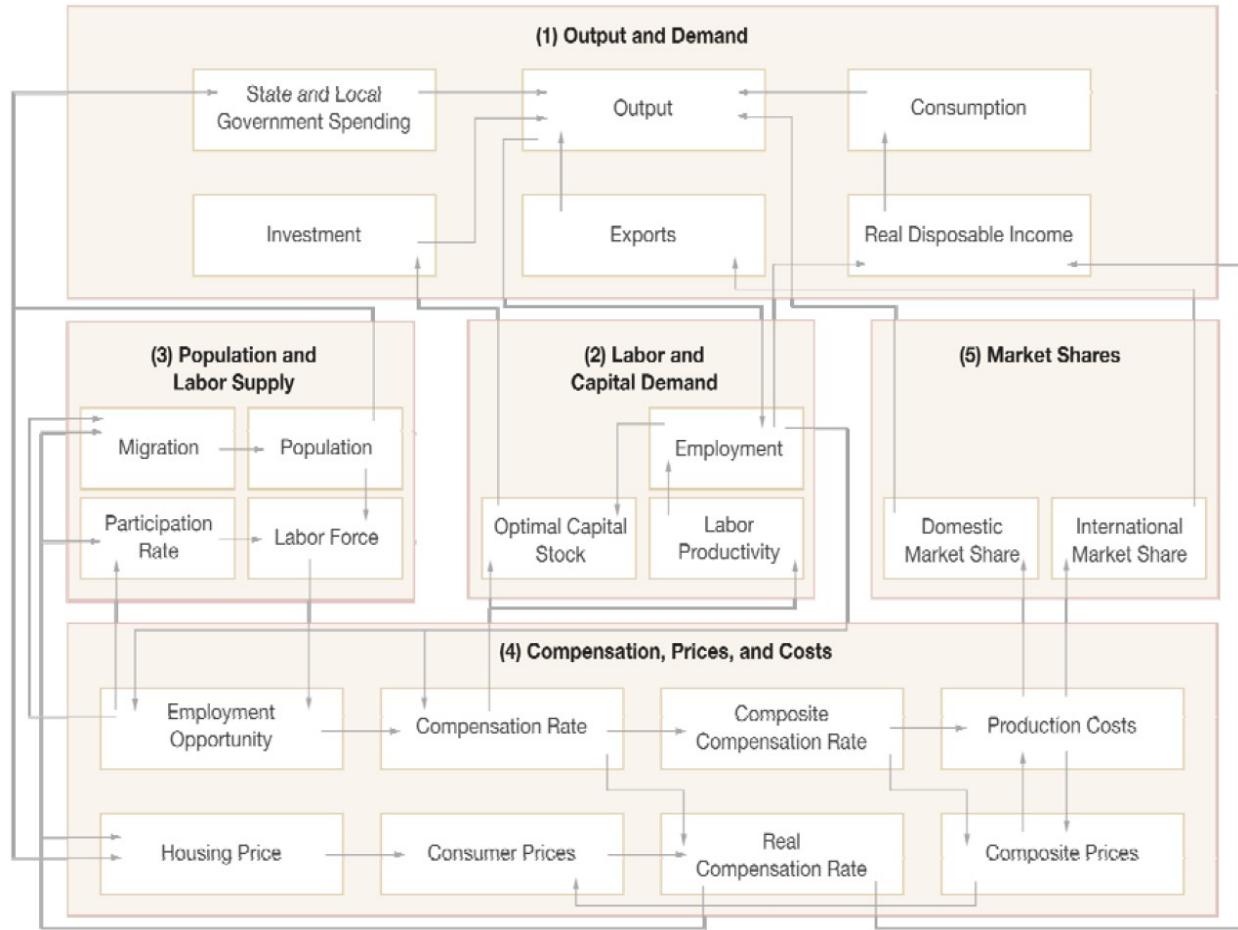
The Compensation, Prices, and Costs block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the wage equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods and services.

These prices measure the value of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs associated with distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of output in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by cost of labor, capital, fuel and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas and residual fuels.

Figure A2. Economic Geography Linkages
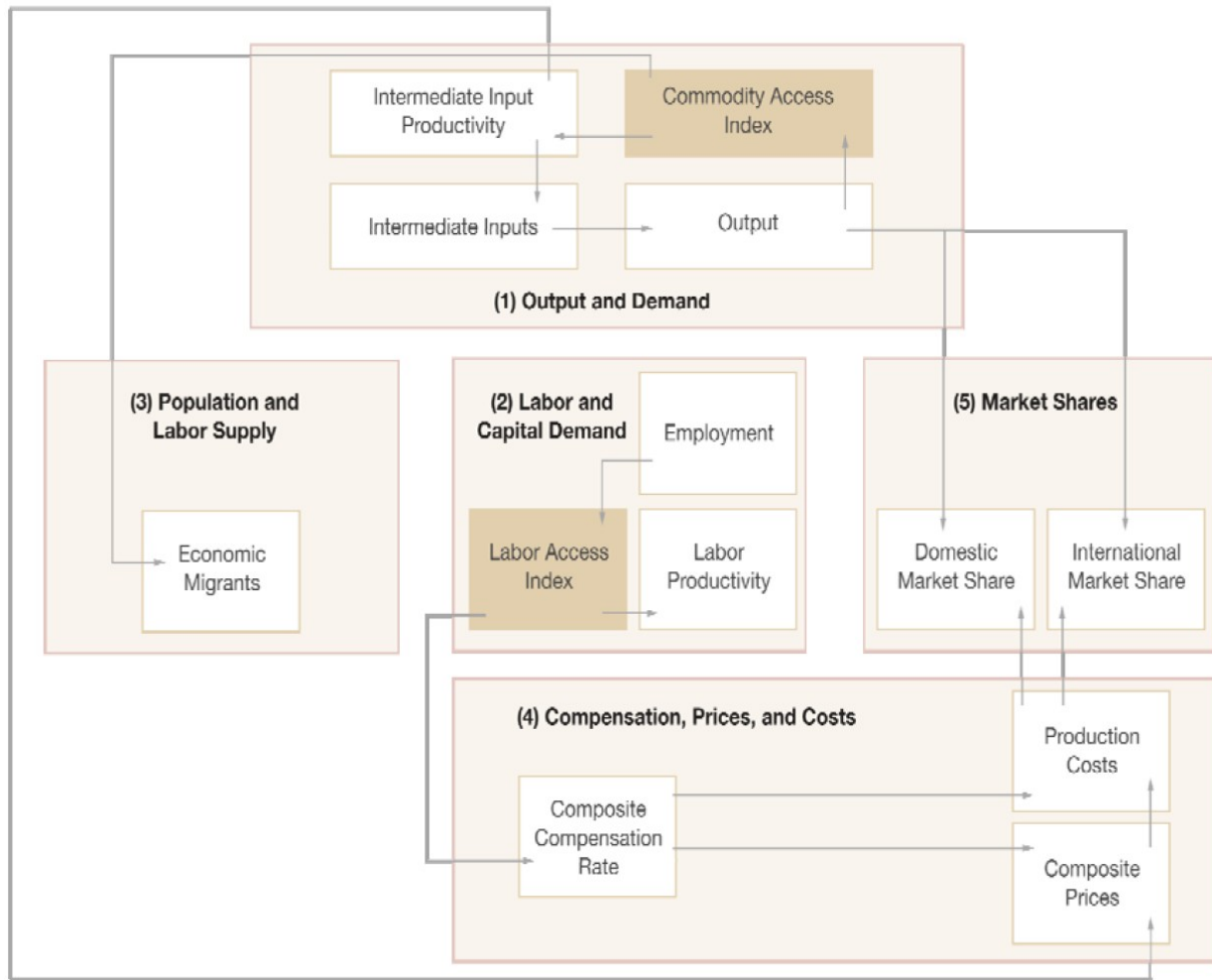
The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing price changes from their initial level depend on changes in income and population density. Regional employee compensation changes are due to changes in labor demand and supply conditions, and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

The Market Shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

As shown in Figure A2, the Labor and Capital Demand block includes labor intensity and productivity, as well as demand for labor and capital. Labor force participation rate and migration

equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the wage equations. The proportion of local, interregional and international markets captured by each region is included in the Market Shares block.

APPENDIX B. Evaluation of Alternative Models

I. OVERALL CRITERIA AND MODEL SPECIFICATIONS

In evaluating economic models, it is first prudent to identify a set of criteria on which to base the decision.

A. Model Performance Criteria:

1. Accuracy. This pertains to the extent the model will yield predictions of macroeconomic impacts that are likely to be close to actual occurrences. Of course, it cannot be absolutely ascertained in advance. Therefore, we depend on standard model features that are likely to enhance accuracy. These include the level of sophistication of the model and its consistency with economic theory, the data that it utilizes, and "goodness of fit" measures where applicable.

2. Scope. This relates to the breadth of coverage of the model. It would include such features as whether it consists only of selected sectors or the entire economy. It also pertains to the number of mitigation and sequestration options that can be included.

3. Detail. This pertains to the degree of resolution of the model. This is indicated by the extent to which the model is divided into a number of sectors and to the number of macroeconomic indicators that can be analyzed with it.

4. Transparency. This pertains to whether the workings of the model can be made clear to those who would utilize its results, as well as whether the model can offer a clear picture of how the results were obtained.

5. Manageability. This relates to the ability of the modeler to develop simulations with the model in a reasonable amount of time. It also pertains to the potential for the eventual transfer of the model to SCAG staff.

6. Cost. This pertains primarily to the expense of building and operating the model itself. It also pertains to the expense of updating and refining the model at a later date.

7. Other. No other criteria were specified during the conference call. However, forecasting ability should be considered.

B. Model Specifications

1. Geographic area of coverage. This pertains to whether the analysis is to be performed only for the SCAG Region, or whether there is a need to include any of the sub-regions. It would be best to use a model that could include the REST of CA and the Rest of the U.S. as well, to better gauge economic and emissions leakage

2. Time of analysis. This refers to the time horizon for the policy simulation.

3. Macroeconomic Indicators. There is a large list, but the conclusion of the conference call was an emphasis on gross state product (GSP) and employment.

4. Sectoral Resolution. It would be preferable to have as much resolution as possible, especially with respect to manufacturing sector detail.

5. Income distribution. The model chosen needs to be able to analyze the income distribution impacts of AB32.

C. Parameter Values

1. Flexibility. This refers to the extent that models can address considerations such as substitution of one fuel or energy technology for another.

2. Productivity and Competitiveness. This refers to the extent that the model can incorporate cost changes and improvements stemming from technological change and the extent to which these considerations affect the region's cost of production relative to that of other regions.

3. Economic Growth. This refers to the extent to which the model can factor economic growth into the baseline forecast.

4. Population Growth. Same as above but with respect to population.

5. Trend Factors. This refers to other secular changes that affect the baseline or the analysis, such as a steady increase in energy efficiency or a steady change in electricity prices.

6. Discount Rate. A 5% real discount rate has been specified. However, sensitivity runs using 2% and 7% percent would be valuable. N7

D. Follow up

1. Presentations. No extensive presentation of the model or its results will be needed for groups outside SCAG.

2. Technology Transfer. This refers to providing the model and the know-how on how to utilize it for other applications to SCAG staff.

II. MODEL EVALUATION

In this section we evaluate the REMI Model and a generic CGE Model (see, e.g., Rose and Oladosu, 2002) in terms of the criteria and other considerations listed in the previous section.

A. Model Performance Criteria

1. Accuracy. Both models are capable of a high level of accuracy. This relates in part to their inherent capabilities, but also depends somewhat on how the models are structured and applied. Both modeling approaches are widely used, indirectly testifying to their abilities on this score. Unfortunately, there are no formal comparisons in the literature between the two (including any type of CGE model). Moreover, analysts rarely go back and assess past projections or impact study results. While there are goodness of fit measures for macroencometric models, they are not available for individual equations or the entirety of REMI. CGE models are "calibrated", i.e., based on a single year's data. This approach is considered less sound than the inferential statistical approach to parameter estimation using time series data inherent in macroeconometric modeling. SCAG and others have experience in assessing the SCAG REMI Model's accuracy. In contrast, a CGE model would have to be built for the SCAG Region for the first time, and thus there is no experience with it in this regard.

Increasing the sectoral resolution will improve the accuracy of both models. Care in factoring in special features of mitigation options, and future technological and structural changes in the SCAG economy would improve accuracy, as would care in modeling mitigation options and linking them to the appropriate variables. Of course, there is a tradeoff between cost and accuracy (see below)

2. Scope. Both models are equally capable of analyzing the entire state economy and the major macroeconomic indicators of interest to this study.

3. Detail. Both models can be disaggregated to as fine a level of detail as desired in terms of economic sectors. However, the 169-sector REMI Model contains more sectors than the standard CGE model.

4. Transparency. Neither approach is a black box. The workings can be readily explained by using simple economic principles. Individual functional relationships (e.g., production functions or consumption functions) can be extracted for further examination, though it is much more difficult to do this in REMI (it would require help from REMI staff).

5. Manageability. Both models are relatively straightforward to use. However, REMI has a major advantage in that it comes with a user's guide.

6. Cost. REMI has a clear advantage here, because SCAG already has the model in hand. It would cost another $35-50K to build the CGE Model from scratch. The costs of preparing the model for application (linking mitigation options to relevant variables) and the actual application are about equivalent to the REMI Model.

7. Forecasting ability. REMI is able to generate forecasts for future baselines. The CGE model cannot do so, and must depend on external forecasts. If only differences in GSP and employment are crucial, rather than their absolute levels, this is not so important.

B. Model Specifications

1. Geographic area of coverage. The REMI Model in the possession of SCAG is essentially a 2-region model—SCAG and the Rest of the U.S., and a third region—Rest of CA—could be added at a modest cost. A three-region CGE model could be built as well, though this would increase the cost of model building by about 50%, and the cost of applying it by about 10%.

2. Time period of analysis. Both models are capable of analyzing the entire time period of 2009-20.

3. Macroeconomic Indicators. Both models are adept at evaluating impacts on both GSP and employment.

4. Sectoral Resolution. The REMI model of 169 sectors is adequate to the task. A comparable sectoring scheme can be developed for the CGE Model. It has the advantage here, if a tailored sectoring scheme is deemed important.

C. Parameter Values

1. Flexibility. The production functions of the CGE model are more sophisticated, and thus it is able to perform better in terms of modeling substitution between fossil fuels and between thee fuels and renewables. This has implications for accuracy as well.

2. Productivity and Competitiveness. Both models can address this somewhat. However, REMI has a more formal and comprehensive approach.

3. Economic Growth. REMI can do this in its forecasts. The CGE model cannot.

4. Population Growth. REMI can do this in its forecasts. The CGE model cannot.

5. Trend Factors. Both models can do this through the inclusion of exogenous variables.

6. Discount Rate.   Both models can do this equally well.

III. OVERALL ASSESSMENT

Based on the analysis of above, the REMI Model has a strong overall edge over a CGE Model to analyze the macroeconomic impacts of AB32. It is not the superior alternative according to all indicators, but it is for most.

A good deal of the edge stems from the fact that SCAG has the model in house and has experience using it. Other major advantages stem from its econometric foundation, including its forecasting ability.

III. REFERENCES

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Addendum – Reponses to SCAG Questions & Comments

1. A comparison of REMI with ARB socioeconomic impact modeling would be helpful.

   CARB used the Environmental Dynamic Revenue Assessment Model (E-DRAM), which is a computable general equilibrium (CGE) model. This is a simulation model of the entire economy based on decisions by individual producers and consumers in response to price signals within the limits of available capital, labor, and natural resources. The strengths of the model are that it explicitly models substitution possibilities (e.g., switching from coal to natural gas). However, several other types of complementary policies are difficult to model in this framework because they involve major technological substitutions of entire processes, rather than just simple inputs. Moreover, a CGE model assumes the economy is always in equilibrium. It is based on a single year of data and on elasticities that are primarily borrowed from the general economic literature and that are not necessarily representative of California. Finally, E-DRAM does not have a forecasting capability. CGE models are used widely to examine the impacts of climate change policy, but most notable at the national level.

   The Regional Economics Model, Inc. Policy Insight Plus (REMI PI$^+$) Model is primarily a macroeconometric (ME) model, though it contains some CGE features in its labor market. An ME is a model that combines statistics and macroeconomic principles to represent the economy. REMI PI$^+$ is based on a time series of historical data for the U.S. and California. It has a forecasting capability, and its baseline forecasts will be made consistent with SCAG forecasts. Simple input substitution possibilities are less sophisticated than in E-DRAM, but the model can more readily accommodate process substitution and technological change. REMI is used widely to examine the impacts of climate change policy but primarily at the state and regional level.

   The research team has experience in using both models, but prefers the use of the REMI Model for this project primarily because, as shown below, REMI has several advantages over the the E-DRAM for used in the SCAG region for this project. In addition, the E-DRAM is not available for the SCAG region economy. Moreover, the team has successfully applied the REMI Model to studies like this in FL, PA, MI, WI, and NM.

    A summary of basic and other features of comparison are:

	REMI	E-DRAM
SCAG Region Specific	Yes	No
Number of Industrial Sectors	166	120
Forecasting Ability	Yes	No
Dynamic	Yes	No
Time of Analysis	2010 to 2020	Year 2020 only

2. Page 7 & 8: The memo states that the REMI model will first be run for each policy option individually, and all other factors will be held constant. Next, the REMI model will be run with the assumption that all policy options will be implemented simultaneously. The model outputs

for these two scenarios will be compared to ascertain how the "simple sum of the parts differs from the whole". There needs to be more description on how this analysis is done, and the factors that are considered in this comparison.

We conduct both "stand alone" and "aggregate" impact analysis of options at both the microeconomic and macroeconomic levels. For macroeconomic analysis we will compute the aggregate macroeconomic impacts of the AB32 policies using two approaches. The first one is the simple summation of the effects of individual policies (interactive effects of these policies have been factored into results through adjustments in the microeconomic analysis phase). In this scenario, we first run each individual policy separately in the REMI Model by feeding in the value changes of the input variables of this policy alone. The REMI outputs of the individual runs are extracted and the simple summation of impacts of all the policies is computed by adding the impact of each run together. The second approach is simultaneous simulation of all the policies, which assumes that all the AB32 policies are implemented concurrently across the region. When we implement the simultaneous run in the REMI Model, we "shock" the model by including all the variable changes of the individual runs together.

Next, a comparison between the simultaneous simulation results and the summation of individual simulation results will be performed. Note that the overlaps between the policy options will be accounted for in the microeconomic analysis and will be eliminated before performing the macroeconomic analysis. Any difference between the simultaneous simulation and the ordinary sum can be explained by the non-linearity in the REMI model and synergies in economic actions it captures. In other words, the relationship between the model inputs and the results of REMI is not one of constant proportions. In actuality, few phenomena scale up in a purely proportional manner. Given that the simulation results are magnitude-dependent and are not calculated through fixed multipliers, it is not surprising that when we model all the policy options together, the increased magnitude of the total stimulus to the economy causes wage, price, cost, and population adjustments to have a different impact than if each option is run by itself.

3. Page 14 #6 under Item C. Parameter Values: 5% discount rates and sensitivity analysis of 2% and 7%.

    The Congressional Budget Office suggests a discount rate of 2% and other agencies and organizations have suggested discount rates as high as 7%. We use 5% real rate (7% nominal) as a compromise and perform sensitivity tests around this number to consider alternative viewpoints.

4. Should the private sector and public sector be using different discount rates?

    We are not saying that the government and private sector should use different discount rates, but rather we are only exploring the implications. One option is to use different rates for public and private investment. Another option, that we prefer to avoid confusion, is to use the same rate but incorporate additional costs of capital for private investment into the cash flows of the NPV by period. In either case sensitivity analysis may be useful as a complement.

5. How will using different discount rates affect the results? There needs to be examples to illustrate the importance of discount rates.

In our analysis of the impacts of the Florida Climate Action Plan, the discount rate we used in the base case analysis is 5%. The NPV of Gross State Product (GSP) gains during the planning horizon (2008-2025) are $37.9 billion.   When a 2% discount rate is used, the Base Case NPV increase in GSP climbs from $37.90 billion to $55.51 billion. When a 7% discount rate is used, the Base Case estimate drops to an increase of $29.77 billion.